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APPLICATION BULLETIN
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PARTIAL DISCHARGE TESTING: What It Is and What It Means

With the introduction of the ISO120 and ISO121, Burr-Brown also introduced partial discharge testing of analog isolation components. We have received several requests for an explanation of the test, what it provides for us and our customers, and how it relates to the more traditional test for isolation voltage ratings. What follows is information about the older test method and what it accomplished, partial discharge, how we test for it, and a comparison of similar products tested using the different methods. Some of this material appears in the ISO120/121 PDS, but bears repeating to give you the whole story.

ISOLATION VOLTAGE RATINGS—WHAT DO THEY MEAN?

An isolation voltage rating is a statement about the *level of voltage* a device can *withstand for long periods of time* with a *high confidence* that the *barrier will not break down*. In the initial development of a part, basic physical and materials design determine the desired rating and long-term, high-voltage life testing of the part verifies it. However, it's impractical to long-term life test every isolation amplifier or power supply that we ship. We need a test that will verify that the part can withstand its rated voltage and give assurance that it will survive that much voltage for long periods of time.

STRESS TESTING

One way to do that is to overstress the part briefly (i.e., subject the part to levels significantly above its *rated* voltage) and then test the part at rated continuous voltage for a short period of time. Alternatively, one can test the part at the overstress voltage for a fixed time, such as 60 seconds (dielectric withstand testing).

We have used both methods, depending on the intended market applications. In either case, the philosophy is something like life testing. In much the same way as accelerated life testing is used to identify infant mortality problems with electronic components, the dielectric withstand testing is used to identify problems with dielectric materials used in isolation circuits.

The choice of overstress voltage is an important one. Many isolation applications see not only the continuous voltage, but also experience transient voltages. Historically, we have used an overstress voltage, V_{TEST} = (2 x Continuous Rating) + 1000V. This choice is used in some UL specifications and is appropriate for conditions where systems transients are not well defined.

However, there are other methods of testing for high-voltage breakdown and some have been around a long time. In 1944, Austin and Hacket published *Internal Discharges in Dielectrics: Their Observation and Analysis.* Since that time, the phenomenon they described, and now termed partial discharge, has steadily gained wider acceptance in the evaluating dielectric materials. For a number of years, the manufacturers of power distribution equipment have used a measurement of RF noise to detect the ionization that precedes high-voltage breakdown. This method is OK for large transformers or similar equipment, but it has not been sensitive enough for small components such as those used in Burr-Brown's isolation amplifiers and power supplies.

Partial discharge testing is similar in concept to the RF noise detection, and recent advances in test equipment and testing standards now make it possible to use this much more sensitive method with our products. Just as Burr-Brown's products are at the forefront of technology, our use of partial discharge testing for some products should be seen as being on the leading edge of testing dielectric materials. We are not abandoning the older, more accepted test standards. However, in preparing to meet the demands for what we believe to be a world-class testing standard, we would like to tell you something about partial discharge, how it's tested, and why we believe it will become the recognized superior method of testing dielectric materials.

PARTIAL DISCHARGE

When an isolation barrier has a defect such as an internal void, the defect will display localized ionization when exposed to high voltage. This ionization starts at one voltage and stops at a lower voltage. These are called the inception and extinction voltages. As high voltage is applied to the barrier, voltage will also build up across the void. When the inception voltage is reached, the void ionizes, shorting itself out. When the voltage across the void drops below the extinction voltage, ionization ceases.

This action redistributes charge within the barrier and is known as partial discharge. If the barrier voltage continues to rise, another partial discharge cycle begins. If the barrier voltage is AC and is large enough, partial discharge cycles will repeat many times during the positive and negative peaks. If the ionization begins and continues, it can damage the barrier, leading to failure. If the discharge does not occur, the barrier receives no damage.

The inception voltage of the individual voids tends to be constant. Therefore, the total charge redistributed within the barrier is a very good indicator of the number of the voids and their likelihood of becoming a failure. Setting a very low limit on the allowable partial discharge in testing gives a very high degree of confidence that HV failure will not occur.

PARTIAL DISCHARGE AND BARRIER EVALUATION

The barrier itself displays an inception and an extinction voltage. The bulk inception voltage varies with the type of insulation, its thickness, and the number of defects. It directly establishes the maximum voltage that can be applied across the test device before destructive partial discharge can begin. Measuring the bulk inception voltage on each part provides an absolute maximum rating for each device.

Measuring the bulk extinction voltage can also provide a lower, more conservative voltage from which to derive a safe continuous rating. In theory, directly from these two measurements one could then specify the maximum transient voltage and continuous voltage ratings. In practice, testing to determine the inception voltage, and de-rating from the inception voltage by a factor related to transients determines the continuous rated voltage.

PARTIAL DISCHARGE TESTING IN PRODUCTION

Once the continuous rating is established, a convenient 100% production test is needed. It should provide firm GO/NOGO information, be very sensitive, be non-destructive and, for economic reasons, be very short. These are the benefits of partial discharge testing! In the late 1980s, manufacturers have produced equipment which can reliably test for very low values of partial discharge. The most recognized standard that we are aware of was developed by VDE in Germany and applies to testing of optocouplers. We have adopted the method described in VDE 0884 to test for partial discharge in our production tests. The test is conducted in two stages. First, a one-second test at rated voltage checks for leakage current. Another one-second test checks for partial discharge (PD) at 1.6 times rated voltage; the level of partial discharge must be <5pC (5×10^{-12} Coulombs). The 1.6 multiplier takes into account the ratio of transient voltage to continuous rating and is specified in the VDE standard.

COMPARISON OF ISO TESTING—NEW AND OLD

The following chart summarizes the differences in time and test voltages for the two test methods. Some of you have expressed feelings that the new test levels and times will leave customers concerned about their validity and application in areas where agency certification (UL, for example) is a must.

Of most concern, from the feedback we received, was compliance of PD testing with UL544 for medical equipment. Most people are familiar with the UL requirement that an OEM test its finished product at 2500Vrms for 60 seconds. This test is required *only* for patient-connected equipment and *not* for all medical equipment. What most people do not know is that UL allows a choice of *two* conditions for this test. The first is 2500Vrms/60s, known as Condition A, and the second is Condition B, requiring a 3000Vrms/1s test. Paragraph 42.2 of UL544 (Revised 1985) allows either test in 100% production testing. Please note that we test the ISO121 at 5600Vrms for one second; we easily conform to Condition B. Since we demonstrate no PD at that voltage, we will easily pass any 2500V test as well.

PRODUCT	ISO102	ISO120	ISO106	ISO121	UNITS
Rated Voltage	1500 2121	1500 2121	3500 4950	3500 4950	Vrms Vpeak
Test Voltage	4000 5656	2500 3535	5697(1) 8000(1)	5600 7920	Vrms Vpeak
Test Time At Max Voltage	10	1	10	1	s
Time At Rated Voltage	60	1(2)	60	1(2)	s

NOTES: (1) Upper limit of our production test equipment for this test method. (2) Proceeds PD test; checks for barrier leakage current.

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